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# Intellimotion

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*PATH – Partners for Advanced Transit and Highways – is a joint venture of Caltrans, the University of California, other public and private academic institutions, and private industry, with the mission of applying advanced technology to increase highway capacity and safety and to reduce traffic congestion, air pollution, and energy consumption.*

CALIFORNIA PATH


# Automating Bus Docking to Improve Transit Service

**J. Bret Michael, PATH/ Naval Postgraduate School**

The technology needed to build automated buses has matured and been demonstrated, but transit operators still need to determine specific ways in which automating buses can improve service. Improved service should result in increased ridership, especially from people who ride buses by choice rather than out of necessity. For instance, service can be improved by increasing accessibility and by integrating bus operation with other modes of transportation, such as subways and light rail transit.

Low-floor buses were a major advance in improving bus accessibility. These buses, pioneered by the German manufacturer NEOPLAN, permit passengers to board and alight on the level, without stepping up or down from the sidewalk at the bus stop docking platform. Level boarding also reduces dwell time — the time a bus spends at a stop. However, if the bus pulls up too far from the curb, and the horizontal gap between bus door and curb is too wide, passengers must first step down to the pavement, rather than across to the bus. Even a small gap could lead to a passenger's falling between the bus and platform, or tripping on the edge of the bus or curb. For some transit users, such as the vision impaired, children, the elderly, or people in wheelchairs, any gap could be a hazard. By automating the docking process whereby a bus pulls up to a bus stop, buses can be made to dock consistently at precisely the desired distance to the curb. This article describes two types of automated docking systems, and summarizes the safety research on this topic conducted by the California PATH Program.

## Automated Docking Systems

Two types of systems have been developed to eliminate the horizontal gap between bus and docking platform. One, a docking assistance system, tells the driver where the bus is with respect to the docking point. For example, the French National Institute for Transportation and Safety Research (Institut National de Recherche sur les Transports et leur Sécurité — INRETS) has evaluated, as part of the GIBUS (Guidage des autobus en station) project, an electronic horizontal display mounted on the dashboard of the bus. This display indicates the lateral distance from bus to docking point, and has been field tested in Grenoble.

The other type of docking system provides for full or partial-authority automatic control of the bus during docking: the bus driver lets the automated system drive, or at least steer, the bus. The VISEE system developed by Renault, for example, uses a partial-authority, vision-based control system to

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steer the bus into the desired docking position. While the system steers, the driver controls the throttle and brakes. Renault, in cooperation with MATRA, is also working on a full-authority electronic-vision based system known as Civis, with testing underway in Paris and other French cities. Cegelec AEG has adapted the fully automated vehicle technology it developed for Channel Tunnel service vehicles for use by full-size transit buses. The bus follows two electronic guide wires embedded in the roadway. Speed is controlled either by the system (using a pre-programmed profile) or the driver. The Cegelec system has been field tested in Newcastle, England, on a Mercedes-Benz bus.

PATH is experimenting with a precision docking system, in which the vehicle follows magnets buried in the pavement. PATH researchers have demonstrated the ability to maneuver a passenger car (Buick LeSabre) very accurately at low speeds, as a kind of simulation of a docking maneuver. The car follows an S-shaped trajectory, analogous to that of a bus approaching a curbside bus stop, with a consistency of better than 1 cm (Figure 1). Researchers expect to be able to repeat this precision docking with a bus as soon as one becomes available. PATH is also investigating design alternatives for fully automated busways (automated highway system lanes dedicated to carrying bus traffic).

The systems mentioned above are based on the concept of electronic guidance, but mechanically based bus guidance systems are still being refined. In the 1980s, the O-Bahn automated bus system, which uses guide wheels with mechanical arms for lateral control, drew the attention of the transit community and was put into service in Essen, Germany, and Adelaide, Australia. The system was not widely deployed, primarily for nontechnical reasons. In 1997, Bombardier introduced a light transit vehicle guided by a single central rail, instead of costly, load bearing double tracks. The Bombardier GLT, like the Civis system, can be operated under manual steering control. Both systems compete with light-rail systems (or trams). Scott McIntosh of London Transport Planning has pointed out that although trams have many appealing characteristics, such as predictable paths of travel, electronically guided rubber-tired buses can provide the same service at less cost.

## Safety Concerns

The systems mentioned above are not considered to be mature in terms of operational experience: docking systems' safety must still be evaluated in the environment of their intended use. For example: in the United Kingdom, the certification and regulation of signaling systems for electronically controlled rubber-tired buses falls under the jurisdiction of Her Majesty's Railway Inspectorate (HMRI), which bases its decisions about certification and other safety matters on its evaluations of "safety cases." A safety case consists of recommendations as to a system's fitness for use in specific operational contexts. The system's fitness is presented in terms of arguments as to how well safety issues have been assessed, and to what extent the implementation of the system addresses safety concerns. Each safety case also includes all evidence supporting the arguments, such as a safety plan, results from a preliminary safety analysis, and records of safety reviews and incidents.

## Safety Cases

PATH has investigated ways to collect, manage, and present safety information about automated docking systems to regulatory, certification, and other decision-making bodies. The work to date has focused on French and British standards, practices, techniques, and tools for constructing and main-

*Left to right:*
*Figure 1–PATH automated test car follows magnets in roadway to simulate bus docking.*
*Figure 2–Near-side bus zone with illegally parked car.*
*Figure 3–Nub stop and queue-jumper lane (ahead of stop). Note truck parked in bus zone.*
*Figure 4–Passengers boarding bus in street.*
*Figure 5–Buses arriving in tandem*

taining safety cases for driverless subway systems. Key findings include:

• Because each safety case may need to be presented to different audiences, a "pre-safety case" could be used to pre-plan the structuring of the safety case to support the generation of different views that could then be addressed in an effective presentation tailored to a specific audience. The Human Communication Research Centre at the University of Edinburgh has done extensive research on this topic.

• Each safety case is a "living" record: it must document all changes to the system, all incidents, and other safety-relevant information. Paper-based safety cases have been difficult and tedious to assemble and maintain over the lifetime of a system, but computer-based tools have now been introduced for constructing, storing, and managing safety cases. The Safety Argument Manager developed at the University of York (England) consists of a suite of tools for inputting safety analysis information and tracing this information back to system requirements and designs.

• Partitioning system functions into different categories can be a useful way of focusing the safety case on a system's most critical functions. Safety cases for French driverless subway systems center on the automatic train protection system, which is responsible for hazard monitoring, emergency braking, and power shutdown, as opposed to automatic train operation and other functions.

• In France, system developers of fully automated subways work directly with independent evaluators appointed by the Ministry of Transportation, who provide the developer with non-binding suggestions for improving the safety case. After this feedback process, the evaluators recommend that the Ministry either approve or deny certification. The Ministry does not dictate, via standards or other means, the contents of the safety case or the manner in which it is presented: this is left up to the independent evaluators and system developers.

• In the United Kingdom, by contrast, there are standing regulatory and certification authorities for all rail-based systems, in addition to a large body of industry standards and guidelines. However, standards for certain aspects of such novel systems as automated buses do not exist. They are expected to be developed as the systems are introduced.

## Field Observations

To develop an initial set of safety considerations upon which to build safety cases for automated bus docking systems, field observations of manual bus docking were made in downtown San Francisco. This area has a high volume of transit bus and other traffic, including pedestrians and bicyclists. Five sites were chosen to observe bus docking for different docking configuration-location pairs: near-side at curb (Figure 2), far-side at curb (see cover photo), nub with queue-jumper lane (Figure 3), and open bay.

Some hazardous conditions observed included: vehicles parked illegally in the bus docking zone (Figure 2), bus drivers permitting passengers to board and alight in the street (Figure 4), vehicles making U-turns, construction barriers forcing drivers to approach a bus stop at a sharp angle, resulting in a large gap between bus and curb, vehicles pulling out of driveways that are partially screened from the driver's view, a truck stopped in front of a nub stop (Figure 3), pedestrians jaywalking as a bus approaches a far-side stop (see cover photo), and buses arriving in tandem with pedestrians standing at the edge of the curb (Figure 5).

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# Automating Bus Docking to Improve Transit Service

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Other features of bus stop design and location that may affect automated docking were noted. At one site, metered parking ran right up to the beginning of the bus zone, but the bus zone was not long enough to accommodate the bus. The current design and location of the other sites would necessitate extreme vigilance by the bus driver in a partially automated system, and very effective and reliable avoidance systems for detecting pedestrians, bicyclists, and other obstacles. The necessary dimensions of bus stops have been published by the International Union of Public Transport (UITP), including pull-in and pull-out angles as a function of bus length and speed, but these guidelines are sometimes not followed due to considerations such as technical feasibility, cost, or acceptability (in terms of public policy) of modifying the existing infrastructure or vehicles. As a basis for recommending changes for the location and design of bus stops to the Institute of Transportation Engineers and the UITP, field studies based on formal protocols should be conducted to identify special docking requirements for partially and fully automated docking.

## Unresolved Issues

Other aspects of automated bus docking than safety remain to be investigated. The safety and technical constraints associated with obstacle avoidance of an automated docking system could possibly result in high development, operation, or maintenance costs. Will bus drivers in Germany, who tend to be well-trained and very experienced, or in London, where there is a high turnover of drivers, accept partial or full automation? Can designs of automated docking systems be developed that will be usable on a wide range of bus chassis, and result in operating costs that are lower than costs for trams? How will automated docking systems interact with collision warning and avoidance systems? These and other issues are fertile areas for further research and development.

*Dr. Michael, until recently a PATH researcher, is now Visiting Associate Professor of Computer Science at the Naval Postgraduate School in Monterey, California. Email: bmichael@cs.nps.navy.mil*

*For information about the other technologies showcased at Demo '98, please visit the Netherlands Ministry of Transport Automated Vehicle Guidance Web site: http://www.minvenw.nl/rws/wnt/avg/index-uk.html*

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# PATH Welcomes Greg Larson as New Caltrans Management Liaison

I am pleased and excited to serve as the management liaison between Caltrans and PATH. While working on the National Automated Highway System Consortium, I had an opportunity to work side-by-side with many of the PATH researchers, and I was always impressed by their dedication, knowledge, and professionalism.

Although I already know many of the people at PATH, I have not previously been directly involved with the PATH Program. As a result I'm still learning about my duties as the management liaison. Fortunately, my predecessor Hamed Benouar and PATH management have developed an effective process for managing the unique research performed by PATH.

I received my Bachelor and Master of Science degrees in Electrical and Electronic Engineering from the California State University, Sacramento. I am a registered professional Electrical Engineer in California and have worked in the engineering field for 16 years, including over eight years with Caltrans. I currently serve as the Acting Chief of the Office of Advanced Highway Systems in the New Technology and Research Program.

I look forward to working with the PATH team to find solutions to our ever-growing surface transportation problems.

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